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INFORMATION ENTREPRENEURSHIP AND EDUCATION .....

Prescriptions for Technological Change

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A B S T R A C T

The possible impossibilities -- these are the products of discovery, invention, and innovation.

How do they come about? This was once a question that historians and philosophers pondered over. It is now a question of import to governors of nations, to educators, to economists, to captains of industry, and to managers of laboratories. For the possible impossibilities are at the root of technological change, and technological change is grist for the mill of economic progress.

A conjecture, supported by logic and experience if not by scientific proof, is that the possession of knowledge as well as a spirit of curiosity and imaginative prowess are major attributes of those who make the impossible possible.

Proposals, experiments, and programs that are under way to test this conjecture constitute the subject of this paper. Specifically, the paper considers two interdependent vehicles for producing and promoting technological change. One pertains to the realm of information handling -- systems for storing and retrieving information, and entrepreneurs for disseminating it and stimulating its scientific and economic exploitation. The other pertains to the role of education as a prime mover in creating a climate for change. In preparing individuals to become agents for change, education is not only altering its own structures, but it is also establishing new patterns of communication and new channels of information flow with other sectors of society.

The process of technological change is not the exclusive province of the information and education communities. Since these groups are at the source of activities that initiate the process, however, it is conceivable that they may be able to make their own contribution to a possibility -- large-scale effective management of technological change.

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PREFACE, OR, ARE INFORMATION ENTREPRENEURS NECESSARY?

Question: Are information entrepreneurs necessary?

Answer: Yes.

Question: Why?

Answer· For at least two reasons, as viewed by two different groups of people, each well able to document its position.

First, there is the group that handles information. They point t to the production of information exemplified by such statistics as:

The growing annual volume of technical reports, approximately 658,000 items in 1961 and 90^,500 in 1965 [1];

The existence of some 38,000 to 40,000 periodicals;

Library of Congress receipts of about 1,000,000 items per year to its 44-45,000,000 collection [1];

The generation of "general-purpose scientific data" pertaining to natural and social phenomena that, for the U.S. government alone, cost $368 million to acquire in Fiscal Year 1967 [2].

They contend that a professional, almost irrespective of his field, can't keep current with new information he should or would want to know about, if left to his own devices, and still have time for his own work. Additional to the volume, the obscurity or scarcity of some materials and language constraints put information beyond his reach for either current awareness or retrospective inquiries. These factors necessitate intermediaries whose principal functions are those of acquiring, organizing, searching, and analyzing information sources to sift from them only those items that interest the professional [3].

1. Alfred E. Busch. "Equating Information With Currency." Records Management Quarterly, vol. 2, no. 1 (Jan. 1968) 5-9, 14.

2. Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1967, 1968, and 1969. Vol. XVII of the Surveys of Science Resources Series. Washington, D.C.: National Science Foundation, Aug. 1968. Rept. # NSF 68-27, p. 72.

3. The term, "professional," is intended here to encompass all types of individuals who need and use information for such purposes as research, development, manufacturing, management, education, social work, etc.

Second, there are the economists, historians of science and technology, and representatives of "progressive" industries. They have observed that:

90% of the long-term increase in per capita output in the U.S. results from technological change, increased educational levels, and other factors not directly associated with increases in labor and capital [4];

40% of the per capita income in the U.S. between 1929 and 1957 derived from "advances of knowledge" [5];

10% of the sales of all manufacturing firms in the U.S. in 1960 were of products developed between 1956 and 1960;

Rates of technological change in firms and industries are directly related to rates of growth of cumulated research and development expenditures.

They make such statements as: "Information is becoming the basic building block of society" [6] and "Our national and corporate preoccupation with the field of science has serves us well in the creation of ins tutions and machinery for generating new knowledge" [7]. Not being information specialists, their recognition of the need for information-transfer mechanisms is expressed through queries on how to translate knowledge to applications and on how to reduce time lags of ten to 20 and more years that often occur between invention (conception) and innovation (application) [8].

A classic study of British firms shows the link between the two groups [9]. The investigators observed a direct relationship between technical progressiveness and financial success. Successful firms exhibited the following characteristics

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4. The four items cited here are reported in: Edwin Ma eld. The Economics of Technological Change. New York: W. W. Norton & Co., Inc., 1968. Pages 4, 5, 7, 31-33.

5. Increases in per capita income signify the occurrence of one or more of the following shifts from less productive to more productive techniques per w ker; the creation or adoption new commodities, new materials, new markets, or new organizational forms; the creation of new skills; and the accumulation of new knowledge. Harvey Leibenstein. "Entrepreneurship and Development." American Economic Review, vol. 58, no. 2 (May 1968) 72-83.

6. A statement attributed to David Sarnoff by Alfred E. .s h, op. cit. (ref. 1).

7. Michael M ichaelis. "Technological and Economic Implications of 3 Percent Growth." American Economic Review, vol. 58, n0. 2 (May 1968) 492-501.

8. See Appendix I that lists time intervals between invention and innovation for 46 inventions. Edwin Mansfield, op. cit. (ref. 4), p.101.

Good information sources;

Readiness to seek information and knowledge of practice from external sources;

Willingness to share knowledge -- technical, managerial, and commercial;

Willingness to acquire knowledge on license and to enter joint ventures;

Effective internal communication and coordination;

Deliberate surveying of potential ideas;

Willingness to arrange for effective training of managerial and technical staff;

Ingenuity in adapting to material and equipment shortages.

One obvious way of introducing some of these characteristics into a firm and of insuring their continuity is through information entrepreneurship.
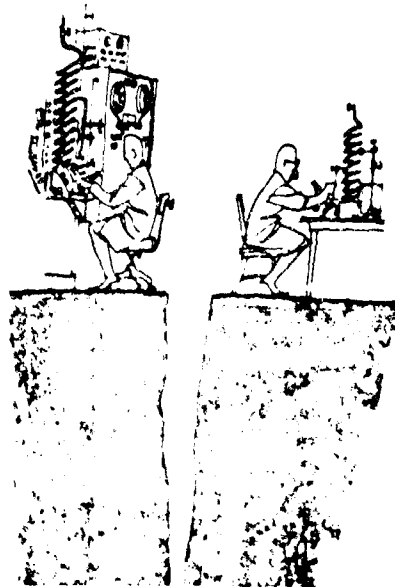
NOT REPRODUCIBLE

Industrial Research, April 1967

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9. C. F. Carter and B. R. Williams, "The Characteristics of Technically Progressive Firms," Journal of Industrial Economics, vol. 7, no. 2 (March 1959) 87-104. The paper gives a total of 24 significant characteristics, as well as 5 characteristics sometimes thought to be important for which the authors found little support.

INTRODUCTION

Technological change has been, at best, a semi-ordered phenomenon. It has depended, in part, on scientific knowledge and technological achievement, one discovery or innovation frequently being necessary to trigger another. It has also depended on economic and cultural factors. For example, power steering was offered commercially 25 years after Francis Davis demonstrated it to ten different people in Detroit (1926-1951), and after it had proved itself on military vehicles during World War II. Manufacturers had a seller's market and they thought the public wouldn't accept the innovation [10]. Jack Rabinow couldn't sell his watch regulator for nine years until he learned of a company official who didn't like inaccurate clocks [11]. The regulator was abandoned by another manufacturer whose salesmen didn't like to tell customers about it! Patent and license policies have also limited or delayed the use and application of some changes.

From case histories, one could hypothesize about events that might have occurred with different patterns of information flow and transfer. Such exercises have seeds of usefulness. They will retain elements of unreality, however, because the hypotheses cannot be tested. Information transfer depends on the behavior of people, on their cognitive processes and personalities and idiosyncrasies, perhaps to a greater extent than it depends on system structures that can be formalized. Therefore, if there is validity to the supposition that information entrepreneurs can cost-effectively improve the exploitation of information so as to enhance technological change (the author considers the supposition valid until proved otherwise), it must be field tested. Moreover, the field tests must be sufficiently intensive and extensive, and of sufficient durations, to be experientially and statistically meaningful.

In two ways (with ramifications within them), beginnings have been made on approaches to order technological change. One route is through the establishment of organizations having the specific mission of exploring procedures that offer promise of achieving information exploitation objectives. The second is through new or modernized university curricula and specialist courses to produce technology oriented information personnel and change-oriented engineers and technologists.

This paper is a brief progress report on these ordering processes.

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10. Edwin Mansfield, op. cit. (ref. 4) p. 104.

11. Jacob Rabinow. "The Process of Invention." In Education for Innovation. (Daniel V. De Simone, ed.) Oxford: Pergamon Press, 1968. At p. 88.

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INFORMATION TRANSFER EXPERIMENTS, OR,
WHAT DO INFORMATION ENTREPRENEURS DO?

So many information systems and services exist that it is difficult to keep track of them. For example, 226 data systems were reviewed in a recent analysis [12]. Brief descriptions of 113 information analysis centers appear in a *Directory of Federally Supported Information Analysis Centers* [13]. Several publications of the National Referral Center for Science and Technology provide guides to U.S. information resources in the fields of physical and biological sciences, engineering, and the social sciences [14]. Operations of these activities are sometimes distinguished as "passive" and "active," depending on whether they are solely responsive to requests (passive) or take the initiative in supplying information (active).

One must assume that each of these activities has a valid *raison d'être* -- coverage of a subject field, or collection of particular items of data, or service to particular user groups such as those in mission-oriented laboratories or business enterprises or geographic regions. Few extensive cooperative ventures exist among the activities.

For one reason or another, the activities have not reached important user groups. By legislation, therefore, the Congress recently launched two significant information exploitation programs. Under the National Aeronautics and Space Act of 1958 (Public Law 85-568), the National Aeronautics and Space Administration (NASA) is directed to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." The State Technical Services Act of 1965 authorizes the Department of Commerce to administer a "national program of incentives and support for the several States individually and in cooperation with each other in their establishing and maintaining State and interstate technical services programs in order that the benefits of federally-financed research, as

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12. Study of Scientific and Technical Data Activities in the United States. Volume I., Part 2. Preliminary Census of Scientific and Technical Data Activities. Washington, D.C.: Science Communication, Inc., April 1968. Final rept., Contract 84-4c2o-67-C-0022. AD-670,608. The other volumes of this study are: Volume I, AD-670,606, and Volume II, Parts A & B, AD-670,607.

13. Directory of Federally Supported Information Analysis Centers. Washington, D.C.: Federal Council for Science and Technology, April 1968. PB-177,050.

14. A Directory of Information Resources in the United States: Physical Sciences, Biological sciences, Engineering. Washington, D.C.: Library of Congress, National Referral Center for Science and Technology. Jan. 1965. $2.25.
    Same title: Social Sciences. Oct. 1965. $..5o.
    Same title: Water. Sept. 1966. $1.5o.
    Same title: Federal Government (With Supplement of Government-Sponsored Information Resources). June 1967. $2.75. All purchasable from the Govt. Printing Office, Washington, D. C. 20402.

State	Administration		Seminars, conferences, courses, etc.		Information dissemination services		Referral services		Field services		Demonstrations		Total	
	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount	No.	Amount
Alabama	1	$6,800	8	$82,450	0	....	1	$3,000	0	....	0	....	10	$92,250
Alaska	1	9,480	1	3,360	0	....	0	....	1	$25,260	0	....	3	38,100
Arizona	1	11,900	9	12,770	0	....	0	....	1	32,530	0	....	11	57,200
Arkansas	1	4,290	12	29,034	0	....	1	4,660	1	27,416	0	....	15	65,400
California	1	16,962	50	64,960	5	$218,851	0	....	0	....	0	....	57	300,773
Colorado	1	5,000	3	6,729	3	23,232	0	....	3	33,503	0	....	10	69,464
Connecticut	2	7,995	4	50,240	2	17,833	1	11,940	1	15,575	0	....	10	103,583
Delaware	0	....	1	15,629	1	5,262	0	....	1	22,501	0	....	3	43,392
District of Columbia	1	3,774	7	30,694	0	....	1	16,492	0	....	0	....	9	50,960
Florida	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Georgia	1	6,177	4	27,019	1	1,011	1	3,500	3	54,633	1	$5,160	11	97,500
Guam	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Hawaii	1	3,345	8	20,000	2	23,300	0	....	0	....	0	....	11	46,645
Idaho	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Illinois	1	26,280	4	60,965	0	....	0	....	1	8,143	1	104,612	7	200,000
Indiana	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Iowa	1	12,870	25	51,100	3	21,030	0	....	0	....	0	....	29	85,000
Kansas	1	11,789	5	11,789	2	8,438	1	5,862	3	58,911	0	....	12	85,000
Kentucky	1	10,100	2	21,508	0	....	2	63,442	0	....	0	....	5	95,050
Louisiana	1	10,000	22	59,693	1	19,141	0	....	0	....	0	....	24	88,834
Maine	1	10,915	6	11,825	1	7,620	0	....	1	11,910	1	11,100	11	53,370
Maryland	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Massachusetts	3	20,746	4	19,717	2	21,888	0	....	0	....	0	....	9	62,351
Michigan	1	20,000	24	54,565	0	....	2	3,405	10	75,240	1	7,590	38	160,800
Minnesota	1	7,057	4	27,645	2	29,029	1	1,000	2	67,160	0	....	10	131,891
Mississippi	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Missouri	3	13,273	19	58,326	0	....	5	40,562	3	13,739	0	....	30	131,900
Montana	1	3,396	8	17,671	1	6,518	0	....	2	22,285	1	1,107	12	70,947
Nebraska	3	11,563	8	8,708	1	10,210	0	....	3	44,519	1	5,000	16	80,000
Nevada	2	12,342	6	2,738	2	8,877	0	....	1	15,443	0	....	11	39,400
New Hampshire	2	7,300	8	18,775	1	9,232	0	....	1	10,148	0	....	12	45,455
New Jersey	0	....	0	....	0	....	0	....	0	....	0	....	0	....
New Mexico	1	14,713	11	9,987	1	5,450	1	2,808	1	17,712	0	....	15	50,670
New York	1	7,000	12	104,603	15	164,002	9	56,593	6	22,802	0	....	43	355,000
North Carolina	1	26,261	1	5,000	3	37,781	0	....	1	60,729	0	....	6	129,771
North Dakota	0	....	0	....	0	....	0	....	0	....	0	....	0	....
Ohio	1	17,790	14	19,942	4	32,292	8	143,759	0	....	0	....	27	213,783
Oklahoma	1	10,527	21	30,547	0	....	0	....	3	33,926	0	....	25	75,000
Oregon	1	3,372	1	5,367	4	26,676	0	....	3	32,785	0	....	9	68,200
Pennsylvania	1	17,230	4	39,985	7	149,160	0	....	0	....	0	....	12	206,375
Puerto Rico	2	20,400	5	4,800	1	12,000	1	5,076	1	41,670	1	1,054	11	85,000
Rhode Island	2	10,666	8	20,170	1	1,700	0	....	3	21,524	0	....	14	54,060
South Carolina	2	10,000	2	32,809	1	6,000	1	3,000	1	20,500	0	....	7	72,309
South Dakota	1	18,636	0	....	2	10,425	0	....	1	7,637	0	....	4	36,701
Tennessee	1	13,800	32	48,086	0	....	0	....	1	34,450	0	....	34	96,336
Texas	1	6,750	5	50,192	3	107,833	1	26,552	0	....	0	....	10	191,327
Utah	1	22,700	6	....	1	13,100	0	....	1	21,500	0	....	9	57,300
Vermont	2	11,727	3	8,944	1	8,758	0	....	1	10,463	1	22,981	8	62,873
Virgin Islands	0	....	4	15,578	1	4,110	0	....	1	3,172	0	....	6	22,860
Virginia	1	14,490	9	14,848	2	22,623	0	....	1	48,039	0	....	13	100,000
Washington	1	2,000	23	43,068	7	43,480	0	....	0	....	0	....	31	88,548
West Virginia	1	4,021	2	2,280	3	21,721	2	5,464	3	26,439	0	....	11	59,925
Wisconsin	1	17,500	62	28,265	2	27,800	0	....	1	34,000	0	....	66	117,565
Wyoming	1	7,173	5	8,264	1	12,000	0	....	1	7,773	0	....	8	35,210
Totals	58	$498,291	482	$1,260,645	90	$1,148,386	39	$403,045	68	$984,037	8	$158,604	745	$4,453,008

Table 1. OSTS Support By Broad Categories of Approved Technical Service Projects for Fiscal Year 1968

well as other research, may be placed more effectively in the hands of American business, commerce and industrial establishments throughout the country." NASA's Office of Technology Utilization (OTU) and Commerce's Office of State Technical Services (OSTS) implement these directives [15].

The STS projects appear, to this author, to be providing the best testing grounds for information entrepreneurship, probably because the projects are not restricted to particular data and information sources. The STS management has not only permitted, but has encouraged, the States to experiment and to apply ingenuity in developing mechanisms for matching available knowledge and human resources with user groups and environmental situations.

Current STS projects vary in scope, quality, resourcefulness, and accomplishments. These variances arise partially from a requirement that States match federal funds for proposed endeavors, and partially from the degree of readiness and sophistication within particular States for information-transfer work. *Table 1* summarizes Fiscal Year 1968 STS expenditures by State and type of information activity. STS grants a few "special merit" awards annually (20 during Fiscal Year 1968) for programs having regional or national significance (e.g., New England marine resources; the nation-wide graphic arts industry). STS has been establishing liaisons with other government agencies and professional groups and their information services. Several awards have been made to these latter services to enable them to provide information to STS projects.

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15. There have been earlier Congressional directives. For example, the Atomic Energy Act of 1946 authorizes the Atomic Energy Commission to disseminate scientific and technical information within its general mission of encouraging participation in research and development on atomic energy and nuclear materials. The AEC sponsors several major information facilities that are highly interactive in their special communities of interest.

The Technological and Scientific Act of 1950 (Public Law 81-776), that led to the establishment of the Office of Technical Services in the Department of Commerce, had the specific purpose of making "the results of technological research and development more readily available to industry and business, and to the general public, by clarifying and defining the functions and responsibilities of the Department of Commerce as a central clearinghouse for technical information which is useful to American industry and business." However, the Congress did not appropriate the funds necessary to operate the program effectively.

Title IX of the National Defense Education Act of 1958 (Public Law 85-864) established the Office of Science Information Service in the National Science Foundation with the responsibility to "(1) provide, or arrange for the provision of, indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information; and (2) undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available." Passive and active information services have been created and expanded under NSF sponsorship, but none have the scope of the NASA and STS activities.

The different characteristics of the various States emerge from an examination of their STS programs. Academic and industrial levels of development influence the activities attempted, their range, depth, and areas of concentration, and, to some degree, their rates of accomplishment. Projects appear uniform, however, in commending person-to-person contact as the most effective mechanism for information transfer. Many activities appear to be understaffed and underfunded, and policies to provide a sufficient financial base for long-term efforts to insure continuity of staff have yet to be worked out. However, the various programs have been gaining recognition and are beginning to reach the populations they were designed for. Several of these are described below.

Pennsylvania's program is one of the oldest in conceptualization, one of the most diversified, and ranks fourth in cost in Table 1. Planning began in June 1965, before the STS Act was signed, in conjunction with broader, already existing State efforts under the aegis of the Governor's Science Advisory Committee to probe opportunities in the State in science, technology, and technology-oriented industries able to contribute to "a strong economic and industrial base for the State" [16]. Pennsylvania, with a population of 11.5 million (1964 statistics) and a labor force of 3.77 million (one-third of the total) engaged in non-agricultural work, has a gross product of about $40 billion. It has 130 institutions of higher education, including 11 accredited engineering schools and 7 accredited business schools. Having depended heavily on extractive industries that have declined in importance since World War II, it now has a rate of growth behind that of many other States, and some areas within the State are among the most depressed in the U.S.A. Pennsylvania has been having difficulty in reorienting the thrust of its economy. Manufacturing employment has been declining; only electrical and non-electrical machinery, printing and publishing, and chemical products showed gains during the 1949-1963 period.

Penntap, the Pennsylvania Technical Assistance Program, the organization that implements the STS Act in the State, has elected to concentrate its finite resources in areas that offer the greatest immediate potential benefit to State industries and the economy. The five fields chosen, in ranked order, are: materials, computer applications, bioscience, transportation, and oceanography. Initial efforts primarily concerned materials technology, particularly new materials, and were expanded, in 1967-1968, to include more phases of materials science ranging from extraction and recovery of raw materials to their refinement, use, and final consumption [17]. Guided by

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16. Five Year Plan, Pennsylvania Technical Assistance Program. University Park: Pennsylvania State University, June 1967.

17. H. LeRoy Marlow. Penntap Annual Report, 1968. University Park: Pennsylvania State University, Aug. 1968.

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its Advisory Council and collaboration with the Governor's Committee, Penntap expects to begin limited penetrations into computer technology and bioscience in 1969.

Table 2 summarizes the Penntap services and their progress for the period June 1967 - June 1968, a total of 13 projects conducted by 7 institutions. A closer look at some of these discloses such activities as:

> *Publication of Special-Interest Materials that Alert to current information, e.g., Powder Metallurgy Science and Technology,* a monthly abstract bulletin (proj. 1001), and a quarterly listing of data file contents of a special-interest information system (proj. 1053);

> *Use of Films for Orientation and Training:*
> a 9-min. movie on the library information system (proj. 1003) explains how the system works; it was shown at an orienting technology transfer seminar and has been requested for showing by two other States;
> a lecture/demonstration series of six 30-min. presentations, available as 16-mm. films or videotapes, highlight recent achievements in material science (proj. 1039); though intended for scientists and engineers in industry, the series should also have appeal to non-specialist audiences;

PROJECT	INQUIRIES	INDIVIDUALS	COMPANIES
1001 PENNTAP Information Centers	82		45
1003 Library Information System	225		79
1004 Audio Tape Library	34	34	9
1006 Textiles in the Engineering Sciences	To be given in Fall, 1968		
1007 Information Switching Program	847		88
1022 MAP Coupling Program		578	263
1028 "Kipling" Project	384		189
1029 Seminar Series on New Materials		152	73
1031 Mobile Library Program	22	274	230
1053 Carbon-Graphite Literature System	Becomes operational in Fall, 1968		
1056 Workshops on Use of Computers	To be given in Fall, 1968		
1061 Instrumental Methods of Color Meas.	To be given in Fall, 1968		
TOTAL	1560	1038	976

1001 Franklin Institute	1029 Bucknell University
1003 Pennsylvania State U	1031 Carnegie Library of Pittsburgh
1004 Pennsylvania State U	1039 Pennsylvania State U
1006 Philadelphia College of Textiles and Science	1053 Pennsylvania State U
1007 University of Pittsburgh	1056 Duquesne University
1022 Pennsylvania State U	1061 Philadelphia College of Textiles and Science
1028 University of Pittsburgh	

Table 2. Summary of Penntap Services
(see ref. 17)

Dissemination of Program Information Through Radio Broadcasts, *e.g.*, Penn State's Division of Broadcasting is producing a 5-min. daily program, *The Sound of Progress* (proj. 1004); it gives capsule reports on new advances in science and technology; it has been used by over 40 radio stations in the States; interviews with scientists are taped for reuse;

Mobile Services, *e.g.*, a "Sci-Tech Mobile" stocked with literature, a microfiche reader, and a reader-printer, makes trips to industry sites, usually in towns remote from technical libraries and urban centers, where staff give orientation talks about Penntap services (proj. 1031);

Production of Computerized Information Files for Dissemination, *e.g.*, a data file on carbon and graphite literature is being constructed for distribution to industries and for an in-house information system (proj. 1053);

Information System Networking, *e.g.*, under proj. 1003, inquirers may send requests to the library of the Penn State campus nearest them (3 branches) or directly to the main library at University Park; requests are sent to the main campus that replies directly to the inquirer, either providing literature or referring him to other sources; of 33 companies that used the library system in 1966-1967, 17 are repeat users; when the service was geographically broadened in 1967-1968, 34 of 62 new company users came from outside the original zones, and 15 of the 62 became repeat users;

proj. 1028 is identifying categories of industrial users, kinds of information sought, and present industrial practices for obtaining information; these data are input aids to other projects;

Seminars and Conferences, *e.g.*, four seminars have been developed to familiarize personnel of non-textile industries on ways of using new fibrous materials (proj. 1006);

seminars on new materials in industry are being directed to small and medium-size companies in a remote area not readily accessible to technical centers of research and development (proj. 1029);

a lecture-and-workshop series (36 hours) on applications of computer simulation techniques to production control and inventory problems encountered by small manufactures (proj. 1056);

a 3-day seminar on the art and theory of color matching for textile dyers and printers, paint and ink manufacturers, paper and container manufacturers, etc. (proj. 1061);

Coupling Programs, e.g., under the auspices of the Materials
Advisory Panel of the Governor's Committee, faculty from six
universities are brought together with scientists in industry
for knowledge and experience exchanges (proj. 1022); seminars,
workshops, and short courses are evolving from this endeavor.

The New York State program has a different over-all emphasis and
is concentrating on fewer mechanisms for information transfer. Of 20
participating institutions, 7 are oriented to economic areas and 13 to
specific technologies. These are listed in *Table 3*. Each of the econ-
omic areas contains diversified industry and commerce. Most of the pro-
jects began in January 1967 [18]. Four of the economic area projects
commenced with surveys of their area's industries and information needs
through questionnaires or field trips or both. Six of the seven report
the establishment of reference and referral services. Five have conduc-
ted orientation seminars and/or conferences and workshops on technology
subjects. One has begun a computer-based selective-dissemination experi-
ment with members of 30 companies, based on journal literature. One is
offering a language translation service. One has compiled a list of
consultants for local industry needs.

Of New York's 13 special technology projects, 6 publish news-
letters or more extensive information periodicals, and 9 have conduc-
ted seminars, short courses, and workshops. Five have prepared lists
of consultants for their specialties. Five are offering bibliographic
and abstracting or indexing services. Two are providing state-of-the-
art surveys and texts that fill information gaps or evaluate and inter-
pret available knowledge in terms readily understandable to industry
users.

North Carolina presents a third picture. Of a population of 5
million, 498,000 are employed in agriculture and 1.5 million in non-
agricultural occupations (42% in manufacturing). The average annual
income per capita was $2277 in 1967 [19]. About 65% of industry em-
ploys fewer than 20 people; 85% of industry employs fewer than 50 peo-
ple. The State has embarked on a vigorous growth program. Cash farm
income in 1966 totaled $1.4 billion; value added by manufacture $6.5
billion (1967); the production value of mining $71.9 million (1966),
and the commercial fishing catch $9.5 million (1966). The North Caro-
lina Assembly voted a 20% salary increase for public school teachers
in 1967, and changed the status of four state colleges to regional u-
niversities.

North Carolina's STS program is limited to a few projects of
three types: information center, education, and industrial liaison ac-

18. Summary Report, Fiscal Year 1967 Annual Report, New York State Technical Services. Albany:
State of New York, Dept. of Commerce, July 1967.

19. The Americana Annual 1968. Americana Corp., 1968, p. 602.

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ECONOMIC AREA PROJECTS		
Rensselaer Polytech	16-county east	newsletter; referral; seminars
State U of of NY, Buffalo	west	Tech Info Dissemination Center; SDI; reference; referral
U of Rochester	Genesee Valley	needs survey; bibliography; reference; referral; translations
Cornell U, Coll. of Engineering	south	industry survey; newsletter; referral; short courses
State U of NY, Binghamton	Broome County	industry survey; seminars; field services
State U of NY, Stony Brook	Long Island	industry survey; referral; seminars; field services
Syracuse U.	central	reference; referral; seminars.

SPECIAL TECHNOLOGY PROJECTS		
New York U.	graphic arts; garment ind.	bibliography & abstract services; course, consultant lists; seminars
Rochester Inst. of Technology	graphic arts	Graphic Arts Progress; text & manual preparation; digests of art.
Cooper Union School for Adv. of Science & Art	pollution	special library development; referral; seminars
Polytechnic Inst of Brooklyn	engineering	seminars; workshops
State U of NY, Coll. Forestry	forest & wood prod.	abstracting & comptr. retrieval; dissemination service
Western NY Nuclear Res. Ctr.	nuclear technology	states-of-art; new letter; referral; needs survey; consultants list; courses.
State U of NY, Coll. Agricul.	food processing	newsletter; referral; seminars; field visits; problems analysis
St. Lawrence U.	geological science	bib. on resources; referral; consultants list; SDI
State U of NY, Coll. Ceramics	ceramics	referral; seminars; continuing ed.
City Coll., City U of NY	computer applications	short courses
Fordham U.		tech assistance for small business
Manhattan Coll.	industrial water pollution	referral; changed orientation
Pratt Inst.	design & pkg. methods	special courses

Table 3. Summary of New York State STS Services

tivities [20]. Information centers are located at the North Carolina State University in Raleigh and at Research Triangle Park, an industrial park near Durham. The latter houses a NASA tape file, provides computer searches, and literature in microfilm form. East Carolina University in Greenville conducts business conferences for executive managers on such topics as management technology and organization concepts. The backbone of the program is the industrial liaison work performed by the School of Engineering at North Carolina State University through its Industrial Extension Service (IES) and Minerals Research Laboratory.

IES was formed in 1955 with a $100,000 annual budget. At present, it has an annual budget of about $360,000 (derived from several sources), and a staff of 23 professional service people, 8 of whom are engineers. It engages in the following work [21]:

Field services. The State is divided into 5 regions. A requirement for personnel doing field work is that they have 10 years of prior industrial experience. About 1000 firms are visited annually. Close communication exists between field representatives and the IES supervisor so that both can keep up-dated on industry needs and IES capability to respond.

Publication. A 4-page monthly newsletter is mailed free to 6000-7000 recipients. Additionally, IES issues handbooks; directories covering facilities, trade associations, research and testing laboratories, registered engineers, etc.; industry-oriented bulletins (practical management guides, states of the art, etc.); and publicity folders. The handbooks, directories, and bulletins are priced publications. A free service is offered for papers in periodicals that are assessed as having particular interest to North Carolina industry that IES reprints. About 200 bulletins are published annually.

Maintenance of special collections. IES acquires educational films that it makes available free on loan. The films concern such topics as supervision, human relations, and industrial engineering. About 1000 loans were made in 1967. IES is building a library of programmed instruction texts. About 300 loans of these materials were made in 1967. Heaviest borrowing was in the areas of industrial methods and management.

Continuing education. IES sponsors short courses, workshops, and conferences; 48 short courses and 5 certificate courses

20. North Carolina Technical Services Program. Raleigh: North Carolina Dept. of Administration, 1968.

21. The description of IES services is based on a talk given by the Supervisor, John R. Hart, at the Second Regional Technology Transfer Seminar held at Texas A & M University, College Station, 22nd Oct. 1968.

were attended by about 3000 people in 1967. These average 6
to 15 hours and include such subjects as basic industrial
statistics, basic electricity, basic concrete technology,
production engineering, and management. IES is encouraging
instruction via TV at industry sites and in community coll-
eges.

Coupling. The University has enabled faculty to participate
in technology transfer through appointments under which pro-
fessors teach half time and do extension work half time.
Field representatives answer such inquiries as they can. IES
staff provide responses in their areas of competence. Faculty
and non-affiliated experts are called in when inquiries re-
quire consultation or study. Up to one day of consultation
is available to firms without charge. Arrangements for fees
are made for more extensive work.

Although the foregoing is not an exhaustive account of all the
mechanisms being explored, it is believed sufficiently inclusive of
current activities of information entrepreneurs.

Datamation advertisement

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Since information, even under favorable conditions, must be digested and assessed by an individual in the context of the rest of his information store, and, since change stimulated by information takes time to be conceived and developed, any meaningful evaluation of the role of information entrepreneurship will have to allow time for the occurrence of events subsequent to the initial transfer of items of information. What this gestation period should be is not now known. It may well become apparent as the role of information reveals itself, if these two factors are interrelated (the author believes they are). Therefore, it is unrealistic to expect evidences of technological change from the activities of the STS programs at the present time. Those that occur are datum points, but they cannot be viewed either as measures or as fortuitous events at this time. Experiences in STS and other information-use programs do have value, however, as feedback to information personnel who can use them in an iterative way for the evolution of appropriate information-transfer mechanisms.

In general, workshops and seminars yield a certain amount of immediate feedback. User satisfaction, of course, depends on whether a proper match was made between content and participant need and comprehension ability. For example, City College (New York) had a "winner" in its short course on the use of computers for design and analysis. The response by civil engineers and architects was so great that class size had to be limited. Another computer methods workshop at Renesselaer motivated one engineer to program one of his company's computations that reduced running time from 4-6 hours to 4 seconds. The popularity of Bucknell's STS-sponsored short courses stimulated the University to expand its technical seminar series at its own expense. Most reported attendance records for this mode of information transfer are good and have encouraged course organizers to continue it.

Plant visits by field representatives also elicit some immediate responses. About half of the IES (North Carolina) workload derives from field visits. Field agents are sometimes disappointed by apparent disinterest when they are reasonably certain they could render genuine assistance. However, IES has found that many people in small industry need think time to get accustomed to something new. Also, individuals are usually fully occupied and tend to set aside matters peripheral to a central task until the task is finished. Therefore, IES is no longer surprised at follow-throughs having 1 to 3 month (and longer) time lags. An econometric study of steel, petroleum refining, and bituminous coal industries showed that new processes were most likely to be introduced when plants were operating at 75% of capacity [22]. There may be critical periods in production cycles for receptivity to information and willingness to innovate.

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22. Edwin Mansfield, op. cit. (ref. 4), p. 167.

Moreover, the nature of an inquiry resulting from a field visit is significant. Bare statistics are important, but should not be over-stressed. It can be expected that requests will be made for literature about a service, once it has been introduced to an individual. Up to 50% of initial requests are of this type. These differ from requests for substantive information that can have various motivations ranging from casual interest to a specific, immediate need in connection with an on-going project.

Field visits are fruitful in a perhaps unanticipated way. A field visit is a learning experience for the field representative as well as for the person visited. From observation of a business or manu-facturing operation, the *visitor* sometimes generates ideas. This has occurred in the IES experience, and in some instances has been of mater-ial benefit to the recipient firm. Representatives from Cornell's food processing group rely heavily on investigative visits to learn about new processing methods and for an appreciation of the industry's infor-mation needs. In Manhattan College's water-pollution project, interac-tion with industrial and professional groups disclosed an unanticipated area of information need. The shift in emphasis has not only reorient-ed the project but resulted in its transfer from the Chemistry Depart-ment to the Sanitary Engineering Department. A St. Lawrence University field trip is credited with starting a building-stone industry.

Though not a direct interface with users, meetings of project staff with advisory and consultant groups constitute remarkable forums for the exchange of information. Advisory councils of STS programs are usually composed of a mix of prominent individuals from commerce, industry, and academic institutions within a State. Their guidance has helped to mold State programs to State needs without costly surveys and lost time through trial-and-error approaches. The close link, in Pennsylvania, between Penntap and the Governor's Science Advisory Com-mittee, not only insures good will for Penntap at high administrative levels but also knits it into broader, State-wide plans. Many projects within a State program have also appointed their own advisory commit-tees. Cooper Union, for example, recognized that its special technology project in air pollution control involved social as well as technical problems. It has enlisted the cooperation of government and industry officials to establish criteria for control systems. A measure of New York City's reliance on this project can be assessed from the reloca-tion of the City's Department of Air Pollution Control to Cooper Union. Thus, though the advisory mechanism is not a direct interaction device, it influences the nature and content of the interface with users.

"Use non-print media for communication whenever you can," seems to be a widely followed principle. Such media "capture" more than one of man's information processing systems simultaneously -- vision and hearing for films, vision and touch for programmed texts, vision and hearing and touch for taped instructional materials with accompanying printed and graphic materials. Combined, these systems probably have more than an additive effect as attention getters and memory aids.

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The potential variety of ways that media can be used increases the likelihood of overcoming individual biases (or idiosyncrasies) against particular forms of "packag ng" information. As observed in formal education situations, media that are adaptable to an individual's information-processing rate make slow learners less visible and, therefore, more comfortable and willing to learn.

The non-print media have found a ready market. One of the most popular of IES's services is its lending library of education films and programmed texts. IES has also succeeded in convincing firms to use plant facilities as part-time classrooms for educational TV. Ironically, IES is having greater difficulty in "selling" the ETV idea to community colleges. Penntap's radio program, *Sound of Progress*, has been able to "spin off" from STS sponsorship. It now draws on wider categories of topics relevant to economic development in the State. It may become a tri-State service, since neighboring States have suggested a joint venture for the region.

Sound of Progress expects to have greater appeal by including topics pertaining to management, finance, and marketing. The program designers recognize that these factors are intrinsically related to the exploitation of new technologies. In the U.S.A., as in developing countries, many small businesses need information other than scientific and technical before they can take advantage of the potentials of technology [23]. These other categories of information are not within the scopes of the NASA and STS programs. A Fordham University project is being discontinued because of this. A questionnaire survey disclosed that small firms in New York's Bronx and Manhattan districts wanted assistance with such internal operations as record keeping, financing, advertising, insurance, and computer use. A frequent criticism of scientific information efforts is that they don't take account of socio-economic realities. Thus, larger rather than smaller firms continue to be the heavy users of scientific information services, because they have the operating base able to cope with the information products.

A long-standing question, antedating the newer information-for-industry programs, is: Are the literature services worth what they cost? These services include the primary-source journals, secondary source journals (abstract periodicals and indexes), selective dissemination schemes, bibliographies, current-awareness announcement bulletins, newsletters, preprint and informal communication devices, document distribution in response to request, etc. Rochester University reported an isolated instance of finding a journal article that saved a firm considerable time and money in connection with a filter for water pollution. Does this justify its search services? Do mailings of newsletters to thousands of firms signify transmission of econo-

23. Eugene Staley and Richard Morse. *Modern Small Industry for Developing Countries*. New York: McGraw-Hill Book Co., 1965. This is an excellent guide for technology-transfer strategists.

mically useful information? Does even the financial independence of
a journal (many require subsidies) mean that it is accomplishing in-
formation transfer? Does the request for a document assure that it
will be read when it is received? There are no conclusively affirma-
tive answers to these questions today.

A host of user surveys give uncomfortably inconclusive answers
[24]. Engineers don't read profession-related texts more than 1 to 2
hours per week, one study found. Another disclosed that preponderant
proportions of industrial research laboratories and small businesses
performing research and development don't subscribe to or know about
leading abstract and index publications. Among subscribers, there was
a 91% use rate over a six-month period, but one suspects that this was
precisely one use in many instances. The technology utilization pro-
grams *are* providing contrasts with earlier experiences. Franklin In-
stitute's information work identified an information gap that the Na-
tional Association of Metal Finishers has given the Institute funds to
investigate. Feedback from users of the Institute's Penntap services
has also disclosed a broad area of information need. The Institute is
now studying the feasibility of establishing a national clearinghouse
for powder metallurgy technical information.

Interviews with individuals requesting NASA "Technical Support
Packages" (TSP) indicate that NASA's device for announcing results of
research and development, known as the *Tech Brief*, is attracting a
readership [25]. The *Tech Briefs* report results of NASA-sponsored
work that have been assessed through screening as having potential
utility. Approximately 1000 are issued annually. The *Briefs* offer
back-up materials, known as "Support Packages," on request. Of 80
individuals interviewed, 36 obtained information about the TSPs they
had requested directly from the *Briefs*; 23 had found references to
the NASA work in the trade press or journals (presumably generated
via the *Briefs*). Only 6 learned about the *Briefs* or TSPs from col-
league-to-colleague transfer that other studies have found to be a
principal transfer mechanism. The *Briefs* are obtained through sub-
scription. Of the 36 subscriptions, 21 belonged to technical staff,
the remainder to libraries. Many subscribers in both categories
route their *Briefs*, selectively or en masse.

The texts of the interviews are good accounts of what techni-
cal people do with information. Several report spending up to a day

24. See Rowena W. Swanson, Move the Information ... A Kind of Missionary Spirit, Arlington, Va.:
Air Force Office of Scientific Research, June 1967. AFOSR 67-1247, AD-657,794. Several user surveys
are reviewed at pages 68-81.

25. Theodore D. Browne et al. Project for the Analysis of Technology Transfer, Quarterly evaluation
rept. 3. Denver, Colo.: Denver Research Institute, Oct. 1968. However, a questionnaire survey ac-
companying 1000 TSPs (512 responses) showed that, of the 412 respondents answering a pricing question,
one-third would not have paid for the package; 41% would have paid from $1 to $5, and 25% $5 or more.
The subject range over which the valuations were assigned suggests individualizing pricing by document.

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or two studying their TSPs and then abandoning them. Others didn't find new ideas in the TSPs, but the published work saved them one to two weeks of experimentation they probably would otherwise have done. Few were able to use the TSP contents without modification. Some used ideas in the TSPs but developed substantially different ways of implementing them. A few are investing considerable time and money in major innovative undertakings.

The interviews make it clear that cost, rather than lack of value of an item of information, *per se*, is a major factor in technology transfer. The research and development share of the total cost of bringing a product to market is, typically, 5 to 10% [26]. Of every 10 products that pass the research and development phase, 5 fail in product and market tests, and only 2 of the remaining 5 become commercial successes. Another study for NASA that examines barriers to technology transfer suggests that there is also a "psychology of innovation" [27].

> *The decision to commit resources represents not a single event at a single point in time, but a series of events which begins with the hiring of personnel, the communication of company objectives, the actions taken to structure the environment within the company, the manner in which past proposals have been received and treated, the mechanisms through which ideas and information flow, etc. Like the number and quality of ideas and innovations that arise in the organization, the commitment decision seems to be directly related to the quality and quantity of technical information investigated and stored in the organization [28].*

Other commentators have described the "propensity" of a firm to innovate, identifying similar "behavioral" characteristics of the firm.

Thus, information cannot be judged out of context of the user's environment. An information service can be cost-accounted from data on savings realized through its assistance. These savings are often difficult to estimate or appreciate while exploratory

26. Edwin Mansfield, op. cit. (ref. 4), p. 106. Subsequent engineering and product design account for 10-20% of the total, tooling and manufacturing engineering for 40-60%, manufacturing start-up for 5-15%, and marketing start-up for 10-25%.

27. E. D. Bennett, F. S. Brandt, and C. R. Klasson, Space Technology: Barriers and Aids to Its Effective Utilization, An Analysis of Problems Encountered by Business Firms Utilizing Space Technology. Austin: University of Texas, Nov. 1967. Working Paper # 68-12. The report categorizes the barriers as environmental, psychological, and organizational. The ideas in this report are not new, but they have been repackaged in an intelligible, thought-provoking way that should give the subject matter comprehensibility.

28. Ibid, p. 37.

studies are in progress. It may be impossible, in some instances, to assess the influence of *an item* of information apart from other items with which it must be associated to be of use. Superbly efficient scientific information systems can be dismal failures if measured by user groups socio-economically unable to take advantage of them. On the other hand, simple systems realistically designed to accommodate to the totality of whatever the user's needs are can be expected to show spectacular cost effectiveness.

EDUCATION, OR, HOW ARE INFORMATION ENTREPRENEURS TRAINED?

Cataloging, compiling bibliographies, and searching for references are librarians' work. The layman to such work sees no distinctions among books, periodicals, technical reports, maps, tables, etc. As viewed by the manager of a firm, therefore, one hires a librarian if the firm needs someone to keep documents in order and to do searching for the staff. Managers have discovered two practical problems to this approach. First, many librarians aren't interested in or trained for work in industrial libraries or work with scientific, technical, and economic information. Second, though low paid, librarians are in short supply. To fill functional gaps, staff members in many organizations have been impressed into or have drifted into information work. Training is often on-the-job with an occasional "quickie" course on rudiments of librarianship. Another group of newcomers are computer personnel who see no limits to the information handling problems they can solve.

There are thus no less than three distinctly different sets of people, with vastly different academic backgrounds, involved in information work today, at least in the U.S.A. Most professional librarians hold bachelor's degrees in the arts or humanities; they qualify as librarians after one year of subsequent study in a library school. Individuals for whom there is no generally accepted occupational title range from subject specialists with Ph.D.'s to high-school graduates. (The title "information specialist" or "information scientist" is often used for those at the mature end of the spectrum). Computer personnel range from senior computer scientists to clever programmer "dropouts" [29].

29. See: A Survey of Science-Information Manpower in Engineering and the Natural Sciences. Columbus, Ohio: Battelle Memorial Institute, Nov. 1966. Final rept., NSF Contract C-428. PB-174,439. The survey estimates that a mean of 11,782 individuals are doing science information work in 1571 organizations. Typical routes of entry into the field are from a scientific activity (25%), library science activity (24%), administration (11%), and academic activity (8%); 17% had been students.

The lead in developing a curriculum for the "information
sciences" came from Britain. Aslib (formerly the Association of
Special Libraries and Information Bureaux) began syllabus dis-
cussions in 1948. The Institute of Information Scientists spun
off in 1958. Instruction based on the Institute's syllabus began
in 1961. It was incorporated in a Diploma course of The City
University (formerly the Northampton College of Advanced Techno-
logy) in 1963, and is now a one-year program for the M.Sc. degree
in the University's Department of Management Studies [30]. En-
trance requirements include an Honours degree in a branch of sci-
ence or engineering, although an economics or social science
degree "will be considered in accordance with the requirements of
the University Ordinance governing the Degree of Master of Science."
The course emphasizes both the "organization of knowledge" and the
"communication of information"[31]. A designer of the British
syllabus distinguishes between its objectives and those of library
science as follows:

> *The information scientist does not need to study the*
> *organization of libraries - he is essentially a user,*
> *not an organizer of libraries. He needs to know only*
> *enough of their organization to be able to use them*
> *intelligently. He can afford to neglect most histori-*
> *cal aspects, as in historical bibliography. He may*
> *need to control or at least be knowledgeable in selec-*
> *tion of reprographic services and of various types of*
> *publication, but it is doubtful whether much more is*
> *needed than an understanding of up-to-date principles,*
> *a grounding on which the information worker can build*
> *if needed. Science graduates will be more prepared*
> *than others for quick assimilation of the technical*
> *principles involved. Library classifications are so*
> *rapidly becoming obsolete for the needs of detailed*
> *information retrieval that the information worker re-*
> *quires only a relatively short study of the principles*
> *of such classifications and of their lines of develop-*
> *ment, as a basis for detailed study of the newer clas-*
> *sificatory principles and their applications in methods*
> *of modern indexing and information retrieval [32].*

A somewhat different school of thought is represented by the
view of the Dean of the School of Librarianship, University of Cali-

30. J.E.L.Farradane. "A Survey of Syllabuses for Education in Information Science." In International
Conference on Education for Scientific Information Work, Queen Elizabeth College, London, 3-7 April
1967. The Hague: Federation Internationale de Documentation (FID), Sept. 1967. Document # FID
422. At pages 11-16.

31. Information Science, M.Sc. Degree Course. London: The City University, 1968. The syllabus is
reproduced in Appendix II.

32. J.E.L.Farradane, op. cit. (ref. 30), p. 14.

fornia, Berkeley, who considers information sciences related in all
fields of study to corresponding components of traditional libra-
rianship [33]. A draft text of the 1968-1969 Berkeley curriculum
is a reorientation ot include information science. The curriculum
focuses on the following three fields:

> *Books and Readers*. This field considers scholarly ori-
> gins, interpretations, and the selection of both printed
> books and other media for the recording of knowledge. In
> addition to general references sources and methods, pro-
> fessional specializations include reference and biblio-
> graphic sources, characteristics and needs of readers,
> and methods of disseminating books and information in
> special literature fields such as science and law.

> *Organization of Documents and Data*. This fie'd includes
> the theory, design, and construction of bibliographic
> schemes by which people gain access to books and informa-
> tion. This encompasses all varieties of file organiza-
> tion and retrieval devices such as classifications, enu-
> merative bibliographies, catalogs, indexes, and question
> answering systems, manual and mechanized.

> *Library and Information Agencies*. This field covers the
> history, goals, functions, government, finance, organiza-
> tion, personnel, line and staff operations, management,
> and housing of the various agencies.

Additional courses are grouped under the heading, *Librarianship and
Library Research*. E :rance requirements include a bachelor's degree
in the arts and sciences "with a strong subject major. An effective
preprofessional training may be planned with emphasis upon any of the
social or natural sciences or humanistic studies, but the prospective
librarian should bear in mind the demands of his future specializa-
tion" [34].

Within the computer science curriculum in the U.S.A., itself
new and evolving, there is movement toward the information sciences.
The ACM (Association for Computing Machinery) Curriculum Committee on
Computer Science published a basic syllabus in March 1968 [35]. It
has three major subdivisions:

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33. See: Raynard C. Swank. "Documentation and Information Science in the Core Library School Curri-
culum." Special Libraries, vol. 58, no. 1 (Jan. 1967) 40-44.

34. Announcement of the School of Librarianship, 1967-1968. Berkeley: University of California, p. 8.

35. "Curriculum 68, Recommendations for Academic Programs in Computer Science." Communications
of the ACM, vol. 11, no. 3 (March 1968) 151-197. The syllabus is given in Appendix III. Recommenda-
tions are made for undergraduate, Master's, and doctoral programs. Course outlines and bibliographics are
included.

Information Structures and Processes, concerned with representations and transformations of information structures and with theoretical models for such representations and transformations;

Information Processing Systems, concerned with systems having the ability to transform information, usually through the interaction of hardware and software;

Methodologies, derived from broad areas of applications of computing that have common structures, processes, and techniques.

Commentaries are being added to the syllabus through a series of invited papers that are amplifying various subject specialties for the Ph.D. The fourth paper of this series is on "information science" which is described as

concerned with the structure and properties of information items, the techniques for information handling, the characteristics of information processing devices, and the design and operation of information handling systems [36].

The rationale for the information science-computer science interface stems from the role of computers as information processing devices and the expectation that computers will eventually "carry out all information processing and dissemination tasks selectively, rapidly, and cheaply" in stand-alone and network configurations. The information science specialty includes courses on data structures, language structures, text analysis, and text processing. Information scientists are expected to contribute to an "understanding of the underlying structures of the information which computing devices are called upon to process."

In addition to undergraduate and graduate academic programs, many other devices for the education and training of "information specialists" exist in the U.S.A. Single courses giving overviews and indicating areas of applicability to particular subject fields are being included in curricula in the sciences and the humanities. There is a plethora of short courses on many different topics that are intended either for up-dating or a general introduction or concentration in a particular area. They are held, variously, for periods of 2 to 3 days,

36. G. Salton, "Information Science in a Ph. D. Computer Science Program," Communications of the ACM, vol. 12, no. 2 (Feb. 1969) 111-117. Six recommended graduate courses are given in Appendix IV.
   The three prior papers in the series are: Robert McNaughton, "Automata, Formal Languages, Abstract Switching, and Computability in a Ph. D. Computer Science Program," Communications of the ACM, vol. 11, no. 11 (Nov. 1968) 738-740, 746; Susumo Kuno and Anthony G. Oettinger, "Computational Linguistics in a Ph. D. Computer Science Program," Commun. of the ACM, vol. 11, no. 12 (Dec. 1968) 831-836; and Bruce W. Arden, "The Role of Programming in a Ph. D. Computer Science Program," Communications of the ACM, vol. 12, no. 1 (Jan. 1969) 31-37.

1 to 2 weeks, or intermittently over several months. They are offered by academic institutions, government agencies, private organizations, and professional societies. Lecturers include individuals who are members of information system operations of these organizations, and invitees having particular qualifications. Quality varies from good to poor. What may have been a seller's market for this type of education is now a buyer's market, but the buyer must still beware [37]. Tutorial sessions at professional society meetings and conferences of special-interest groups are also becoming popular to fill gaps and guide the newly initiated.

There is little recognition in all this of the information entrepreneur. Responsibilities of the information scientist trained in Britain include

> *finding, comparing, sifting and evaluating information....*
>
> *tasks of presenting valid comparisons between different statements or research results, of indicating confirmations of facts or inconsistencies between different reports, and of drawing the attention of the researcher to duplications of work, gaps in available information, and other types of information which may bear upon the problems involved* [38].

The entrepreneur's role is

> *to locate new ideas and to put them into effect. He must lead, perhaps even inspire; he cannot allow things to get into a rut and for him today's practice is never good enough for tomorrow. In short, he is the Schumpeterian innovator and some more. He is the individual who exercises what in the business literature is called "leadership." And it is he who is virtually absent from the received theory of the firm* [39].

37. Marilyn C. Bracken and Charles W. Shilling. Education and Training of Information Specialists in the U.S.A. Washington, D.C.: George Washington University, Biological Sciences Communication Project, May 1966. This survey reports mainly on the degree programs in information science available in 20 universities and institutes. Appendix V of this paper presents the outline of a current short course on information retrieval systems of the American Management Association as an illustration of one of the better conceived offerings.

See also: International Conference on Education for Scientific Information Work, op. cit. (ref. 30). This is an excellent collection of papers on various curricula and philosophies of education for information work prevalent today in Europe, the U.S.A., and several developing countries (India, Israel).

38. J.E.L.Farradane, op. cit. (ref. 30), p. 12.

39. William J. Baumol. "Entrepreneurship in Economic Theory." American Economic Review, vol. 58, no. 2 (May 1968) 64-71.

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The British information scientist and others trained, under whatever name, are entrepreneurs when they actively link information resources with user groups. To be able to do this, they must know about the information resources, they must be subject competent, and they must know how to disseminate information effectively. Embedded in these requirements must be the ability to organize information; knowledge of how to store and sort it; and cognitive and personality traits that enable perception of user need, intelligible communication, and effective information transfer. "Information" is not information until it is accepted as such and used. The principal job of the information entrepreneur is to identify items of information and bring them to points of use.

Components of the foregoing curricula can be assembled to give individuals the knowledge they need to be information entrepreneurs. The curricula are more likely to produce theoreticians or information engineers than entrepreneurs, however, unless they are able to instill abilities to think independently, to create, to express thoughts clearly, and to reason logically with and motivate others.

THE NEW LOOK, OR, EDUCATING FOR CHANGE

Good information entrepreneurship is necessary, but not sufficient, for information transfer. Transfer requires a receiver. In the author's opinion, a recipient is not a receiver until he interacts with the information communicated to him. He does not have to use the information in the sense of modifying any of his current work or thoughts or plans. He does, however, have to recognize the information as relevant or non-relevant to his interests. Recognition is a processing of information, an account-taking of it. Most relevant items of information may be items a receiver should be aware of, though they induce no immediate changes. Recognition is a filtering and evaluation process by which the receiver selects and stores information (mentally, if not physically) for future need.

Information that does suggest investigation and possible change can pose challenges or threats to prevailing patterns of thought and operation. People seek equilibria and stable states. Change upsets and disturbs. Our teaching methods have not educated for change [40]. Stories of exploration and discovery often spark

40. See: Paul R. Lawrence. "How to Deal With Resistance to Change." Harvard Business Review. vol. 47. no. 1 (Jan-Feb. 1969) 4-6, 8,10,12,166,168,170,172,174,176.

the imagination of youngsters. Few Christopher Columbuses appear
to survive the teen ages. Change, after it occurs, is history. It
is taught as what "they" did. Laboratory experimentation is by the
"cookbook," and offers little opportunity for creativity and discovery.

Current and proposed reforms in engineering and technical education have significance for information entrepreneurship for technological change, because they aim toward the development of individuals receptive to change. Historically, engineering is the profession having production responsibilities for society. Engineering's products range from "quick fixes" to large-scale undertakings that include extensive research to convert scientific knowledge to engineering "know-how." Today, the scope of engineering is becoming broader. Curriculum designers envision engineering as a bridge between science and human needs. Their point of view is that

> *the professional engineer must assume the initiative in*
> *helping to solve problems which in the past have been*
> *shrugged off as political, economic, social or as head-*
> *aches for business or government. Instead of letting*
> *others come to him to design new patches on old garments,*
> *the professional engineer should help bring to bear the*
> *discoveries of science to design new garments, new appro-*
> *aches, and new solutions* [41].

Reforms pertain both to the substance of curricula and to
techniques for presenting it. The goal of new teaching methods is
to increase student involvement in inventive and innovative work.
The following are exemplary techniques that are being incorporated
into some curricula:

Study of case histories that illustrate the innovator's
problem-solving methods;

Assignment of unsolved case problems to stimulate creative thinking;

Project laboratories in which students design, construct,
and evaluate simple devices for in-depth experience on
specific problems;

Encouragement of graduate theses covering the design of
new and novel systems, products, and processes;

41. The quotation is attributed to Prof. Douglas Browne of Princeton in: Frederick C. Lindvall, "Engineering: Its Past, Its Present, and Its Future." In Engineering, A Look Inward and A Reach Outward (Arnold Reisman, ed.). Madison: University of Wisconsin- Milwaukee, Summer 1967, pages 11-19, at p. 18.

Lectures supplementing or woven into standard courses
in physics, chemistry, and the engineering sciences that
analyze applications of theory, engineering failures, and
current research frontiers;

Seminars on such topics as invention from the inventor's
viewpoint, marketing, the role of patents and the patent
literature, and finding new uses for existing discoveries;

Part-time industry or research laboratory internships,
preferably of a several-year duration;

Special courses for exceptional students;

Guest lectures and courses by leading engineers from in-
dustry and government;

Studies of complex new engineering systems performed by
multidisciplinary faculty-student teams from engineering,
science, business, and the social sciences [42].

Cambridge University in England started a novel pilot program
in 1966. It is a one-year post-graduate course for engineers aimed at
bridging the gap between university experience and industry needs,
particularly in design and production. The course combines site vi-
sits to industrial establishments with lectures. Each student must
report on a minimum of 45 problem assignments accumulated from 31 dif-
ferent establishments. Lecturers are recruited based on their special-
ist knowledge from universities, industries, research laboratories,
industrial associations, and trade unions. The students travel in
groups that vary in composition from week to week. The pace is stren-
uous. The students are selected by their industry employers who pay
a small fee to the University and their employees' salaries. Design-
ers of the course believe that it is teaching industry about the en-
vironment industry must maintain to stimulate and retain university
graduates [43].

Curriculum reforms will probably be gradual and undergo several
modifications as engineering establishes itself at the confluence of
the natural and social sciences. During World War II, engineering re-
search began to overlap applied science as engineering design became
more dependent on fundamental knowledge from physics, chemistry, mathe-
matics, etc. In the 1940's, engineering branched in two directions,
toward such specializations as thermodynamics, circuit design, relia-

42. William Bollay. "New Directions in Engineering Education." In Education for Innovation, op. cit,
(ref. 11) 63-73.

43. J. M. Sharman. "Bridging the Gap - An Experiment in Graduate Training." In Sira Conference on
Innovation for Profit held at Eastbourne, 6-8 May 1968. London: Adam Hilger, Ltd., 1968. At pages 94-
104.

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bility, and sales engineering, and toward generalization in the design
of systems. The purview of systems design now extends from small as-
semblies to complete mechanical and electrical systems, weapon sys-
tems, large industrial complexes, and communications, power and trans-
portation systems in the socio-economic sphere. Traditional depart-
mental distinctions in engineering no longer match with the nature of
today's industrial problems. For example, industry is concerned with
resource utilization and optimization strategies, not with metal cut-
ting or circuit control problems *per se*, that necessitate more than
the application of mechanical or electrical engineering techniques.
The engineer is increasingly interfacing with the psychologist, socio-
logist, businessman, and government administrator as he applies his
tools of analysis, design, and experimentation to social systems.
Humaristic and social sciences studies are being incorporated into
already overburdened engineering curricula. One of many proposals is
the establishment of a basic baccalaureate in engineering science or
fundamentals of engineering followed by graduate work in the social
sciences [44].

As with technological change, large-scale adoption of the fore-
going and other education innovations depends on many factors. A
principal requirement is a capable faculty who, in turn, need proper
institutional support. This support not only includes encouraging
faculty to experiment with methods and curricula, but also enabling
faculty to keep their competence up-to-date through research, summer
and sabbatical study, and consulting activities with industry; re-
warding faculty for creative contributions; and providing faculty
with such collateral assistance as clerical and laboratory staffs and
operational budgets [45]. Environmental factors influence the moti-
vational drives of both faculty and students. A favorable environ-
ment can be stimulated through such devices as:

>Working relationships with industry that keep universities
>aware of industries' manpower and problem needs and indus-
>tries aware of universities' programs;

>Enhancement of the public "image" of the creative person
>through films, TV, etc.;

>Rewards for creative work through local or national compe-
>titions and engineering "fairs;"

>Summer conferences and faculty exchange programs that
>facilitate communication and program development across
>institutional boundaries;

44. See: Frederick C. Lindvall, *op. cit.* (ref. 41) and the following two papers in this collection:
Gerald Nadler, "Engineering Research and Design in Socio-Economic Systems," pages 21-36, and Martin
L. Taft, "Design for Education: A Systems Approach," pages 41-60.

45. Robert B. Banks. "The Motivation and Development of Faculty." In *Education for Innovation*, *op.
cit.* (ref. 11) 125-127.

Fellowship selection procedures that emphasize creativity;

Enlistment of moral and financial support from alumni groups, foundations, and government agencies [46].

Technical education is also becoming "a growing challenge in American education." Technical education consists of the education programs at post-secondary school level that combine the learning of complex skills with sufficient scientific and technological theory to prepare technicians to provide close support to scientists and engineers through the range of work from basic research to industrial production [47]. The programs are of 2 to 3 year durations, and are applications oriented. Though technological change is becoming more rooted in the explcitation of scientific and technical information, properly educated technicians are a potentially important group of receivers for information entrepreneurship.

Technical education has suffered from a lack of understanding of the position of the technician and a lack of recognition of his training as higher education. The profession is sensitive to technological change (causing instability of technical occupations). Many students who enter technical education programs are not properly qualified or motivated, and 50% of enrollees don't graduate. Current curriculum reforms are considering a core of science, mathematics, and technical courses to enable technicians to adapt with little additional training to a variety of occupations. Many educators believe that technical education offers a good laboratory for experimenting with new teaching methods. The need for properly trained faculty may be more severe for technical education than for engineering. University education does not appear to be the best preparation for technical educators. One suggestion is a masters degree program that includes appropriate pedagogy and exposure to the working environments of technicians. Faculty and students also need motivational stimulants, particularly in view of the widely misunderstood and unrecognized role of the technician.

It was noted above that information can pose challenges and threats in environments that resist change. Conversely, dynamic environments dependent on high-quality information flow impose stringent demands on information services. Both the information handling activities discussed above and education reforms, together with their interfaces with industry, are presently in early developmental phases. Mismatches exist at all boundaries and are likely

46. See: Ray E. Bolz and Robert C. Dean, Jr. "Strategies and Teaching Methods," In Education for Innovation, op. cit. (ref. 11) 128-166.

47. Technical Education, A Growing Challenge in American Higher Education. Report by the Commission on Science Education of the American Association for the Advancement of Science. Washington, D. C.: AAAS, July 1968. Misc. publication 68-14.

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to continue during growth phases, i.e., services will fall short of
user requirements and recipients of information will fail to recog-
nize its value. These are phenomena that arise in the interaction
of complex systems. *Of fundamental importance to glob ' progress
is that all components of the system be aware of their interdepen-
dence.* This mutual awareness can provide beneficial direction and
reinforcement to each. No element in this intermeshed structure
could, by itself, produce technological change, but cooperative in-
teraction might well permit ordered programming of technological
change.

CONCLUSIONS AND IMPLICATIONS

This is a progress report on two sets of activities that are
evolving in society today for the purpose of aiding and accelerating
the orderly progress of technological change. The goals of informa-
tion handling work and information entrepreneurship are to make grow-
ing information resources usable in accordance with need and to pro-
mote the use of these resources for technological change. Education
reforms are introducing new programs and substantial revisions in
existing programs for training individuals to think and to communi-
cate and to interact in ways conducive to technological change.

This paper concerns the driving forces on technological change.
Technological change is, however, itself a driving force on national
and international economies and social structures, and on the lives of
all individuals. If progres can be ordered, who should establish the
order? Are the "social system of science and technology and the con-
ditions of research to which we have become accustomed after 300 years
of a tradition that seemed changeless" destined shortly to attain ma-
turit, and change under their own weight? [48]. Should governments,
through technico-economic competence built into their own machinery
and in collaboration with appropriate sectors of society, set the
patterns for future economic and social developments? [49]. Can fore-
casting methods and "brainstorming" techniques aid in predicting

48. Derek J. de Solla Price, "The Scientific Foundations of Science Policy." Nature, vol. 206, no.
4981 (April 1965) 233-238.

49. K. Pavitt, Government and Technical Innovation, Paris: Organisation For Economic Cooperation
and Development, Jan. 1966, Publication = 19,766.

technological changes and their consequences? [50]. Does the hypothesis, supported by fact, that "the faster the rate of change in the modernization process within any given society, the higher the level of political instability within that society," suggest drawbacks to planning or accelerating technological change? [51].

Reorientations in thinking, work patterns, and environmental interactions are needed to generate and adapt to technological change. Reorientations occur slowly at different rates for different individuals and different groups. The nature of the change and the size and composition of the group affected by the change influence rates of acceptance and adoption. Resistance to change on a national or international scale is likely to exceed that within a corporation or small geographic region. A fundamental change is likely to evoke more resistance than a minor change. A change, injected into a system without allowance for its effects on other components of the system, can cause gross instabilities.

Education for technological, economic, and social changes on national and international levels is far more complex than the difficult-to-achieve education reforms discussed in this paper. Predictions and hypotheses based on old sets of conditions and methodologies may not apply to new approaches. Changes that benefit mankind seem worthwhile to pursue, but ch the proviso that available knowledge, fragmentary as it is, be incorporated into action plans. Systems engineering (some would say *cybernetics*) teaches that, as man interacts with other components in large systems, he changes his own as well as the entire system's characteristics. Systems engineering also teaches that there is no single optimum solution to a problem. The engineer knows that to solve a problem, he must start with what he has. Each step gives him experience, information. Through iterative processing, he eventually reaches his goal.

SIC Automatic, Winter 1969
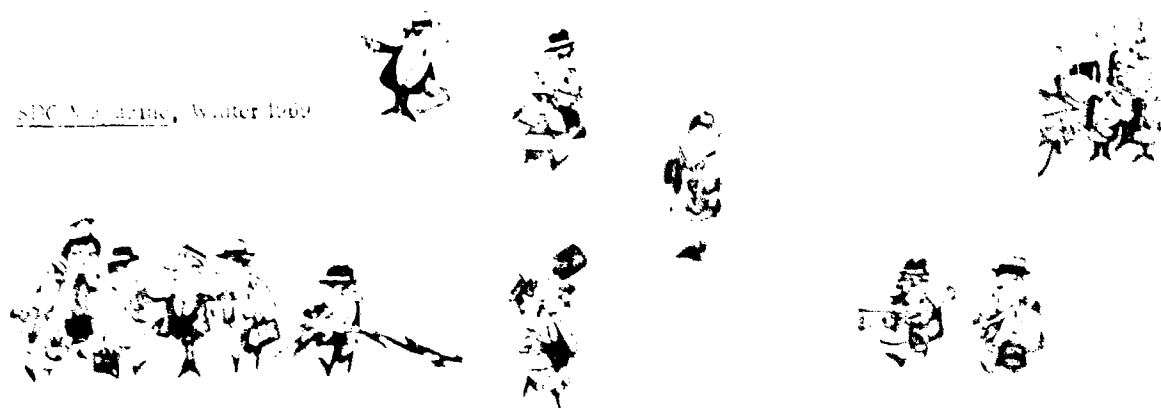
  . Long Range Forecasting Methodology, A symposium held at Alamogordo, New Mexico, 11-12 Oct. 1967. Arlington, Va.: Office of Aerospace Research, 1968.

  51. Harold A. Linstone. "The Mirage Studies and Some Implications." In Long Range Forecasting Methodology, op. cit. (ref. 5c) 71-96.

ESTIMATED TIME INTERVAL BETWEEN INVENTION AND INNOVATION

46 Inventions, Selected Industries [*]

INVENTION	INTERVAL (YEARS)	INVENTION	INTERVAL (YEARS)
Distillation of hydrocarbons with		DDT	3
heat and pressure (Burton)	24	Electric precipitation	25
Distillation of gas oil with		Freon refrigerants	1
heat and pressure (Burton)	3	Gyrocompass	56
Continuous cracking			
(Holmes-Manley)	11		
Continuous cracking (Dubbs)	13	Hardening of fats	8
"Clean circulation" (Dubbs)	3	Jet engine	14
Tube and tank process	13	Turbojet engine	10
Cross process	5	Long-playing record	3
Houdry catalytic cracking	9	Magnetic recording	5
Fluid catalytic cracking	13	Plexiglass, lucite	3
Gas lift for catalyst pellets	13	Cotton picker	53
Catalytic cracking (moving bed)	8	Nylon [b]	11
Safety razor	9	Crease-resistant fabrics	14
Fluorescent lamp	79	Power steering [c]	6
Television	22	Radar	13
Wireless telegraph	8	Self-winding watch	6
Wireless telephone	8	Shell molding	3
Triode vacuum tube	7	Streptomycin	5
Radio (oscillator)	8	Terylene, dacron	12
Spinning jenny	5	Titanium reduction	7
Spinning machine (water frame)	6	Xerography	13
Spinning mule	4	Zipper	27
Steam engine (Watt)	11	Steam engine	
Ball point pen	6	(Newcomen)	6

Source: J. Enos, *op. cit.*, p. 307–308.

[a] The first eleven inventions in the left-hand column were those that occurred in petroleum refining.

[b] Actually, this is the length of time between the beginning of fundamental research by DuPont on superpolymers and the production of nylon on the first commercial unit.

[c] This figure pertains to Vickers' booster units, not Davis's system. See section 3.

[*] See Edwin Mansfield, ref. 4, p. 101.

SYLLABUS, INFORMATION SCIENCE, , Sc. COURSE

City University, London [*]

I. Information Gathering

SOURCES OF INFORMATION
Their characteristics, comparative evaluation, and appropriate means of exploitation.

PUBLISHED AND UNPUBLISHED SOURCES
Individual sources and organizations; oral, visual, and non-documentary sources.

BRITISH AND FOREIGN SPECIALIZED SOURCES
Libraries learned societies, trade organizations, research associations, national and international bodies.

METHODS OF LOCATING SOURCES
Making efficient use of them, in particular, for obtaining detailed information.

II. Information Storage and Retrieval

CLASSIFICATION THEORY
Hierarchic, scientific, by synthesis; applications of computer logic; logical principles and advanced research methods; principal classification systems at present in use.

INFORMATION STORAGE AND RETRIEVAL
Indexing; large-scale mechanical and electronic methods; information retrieval systems; computer-production of indexes and selective dissemination of information; problems of testing systems; statistical evaluation.

DEVELOPMENTS IN LINGUISTIC AND SEMANTIC ANALYSIS
For information storage and retrieval.

III. Dissemination of Information

FLOW OF INFORMATION
Theory of human communication and the problems in research and industry.

[*] See ref. 31

ABSTRACTING

And the production of abstracts journals.

ORGANIZATION OF THE FLOW OF INFORMATION

In research, industry, and government; role of international
organizations in the dissemination of information; liaison and
advisory services.

APPLICATION OF RESULTS

Of research and development.

ERGONOMICS

Its application to information work.

IV. Legal and Commercial Aspects of Information Work

LAW

Patents, Trade Marks, Registered Designs, and Copyright Law.

STANDARDS

National, international and industrial standards; organizations
dealing with standards.

V. Administration and Other Aspects of Information Work

MANAGEMENT OF INFORMATION DEPARTMENTS

Staffing problems and organizational relationships; economics of
information services.

REPRODUCTION AND PRESENTATION OF INFORMATION

Copying and reproduction methods; methods of typography,
printing and illustration in relation to problems of efficient
communication.

LANGUAGE STUDIES

Tuition in one foreign language to good technical reading standard;
principles of translation and transliteration, and linguistic problems
in information work.

SYLLABUS, ACM CURRICULUM COMMITTEE RECOMMENDATIONS

FOR ACADEMIC PROGRAMS IN COMPUTER SCIENCE *

I. INFORMATION STRUCTURES AND PROCESSES

This subject division is concerned with representations and transformations of information structures and with theoretical models for such representations and transformations.

1. DATA STRUCTURES: includes the description, representation, and manipulation of numbers, arrays, lists, trees, files, etc.; storage organization, allocation, and access; enumeration, searching and sorting; generation, modification, transformation, and deletion techniques; the static and dynamic properties of structures; algorithms for the manipulation of sets, graphs, and other combinatoric structures.

2. PROGRAMMING LANGUAGES: includes the representation of algorithms; the syntactic and semantic specification of languages; the analysis of expressions, statements, declarations, control structures, and other features of programming languages; dynamic structures which arise during execution; the design, development and evaluation of languages; program efficiency and the simplification of programs; sequential transformations of program structures; special purpose languages; the relation between programming languages, formal languages, and linguistics.

3. MODELS OF COMPUTATION: includes the behavioral and structural analysis of switching circuits and sequential machines; the properties and classification of automata; algebraic automata theory and model theory; formal languages and formal grammars; the classification of languages by recognition devi   syntactic analysis; formal specification of semantics; syntax directed processing; decidability problems for grammars; the treatment of programming languages as automata; other formal theories of programming languages and computation.

II. INFORMATION PROCESSING SYSTEMS

This subject division is concerned with systems having the ability to transform information. Such systems usually involve the interaction of hardware and software.

1. COMPUTER DESIGN AND ORGANIZATION: includes types of computer structure—von Neumann computers, array computers, and look-ahead computers; hierarchies of memory—flip-flop registers, cores, disks, drums, tapes—and their accessing techniques; microprogramming and implementation of control functions; arithmetic circuitry; instruction codes; input-output techniques; multiprocessing and multiprogramming structures.

2. TRANSLATORS AND INTERPRETERS: includes the theory and techniques involved in building assemblers, compilers, interpreters, loaders, and editing or conversion routines (media, format, etc.).

* See ref. 35

3. COMPUTER AND OPERATING SYSTEMS: includes program monitoring and data management; accounting and utility routines; data and program libraries; modular organization of systems programs; interfaces and communication between modules; requirements of multi-access, multiprogram and multiprocess environments; large scale systems description and documentation; diagnostic and debugging techniques; measurement of performance.

4. SPECIAL PURPOSE SYSTEMS: includes analog and hybrid computers; special terminals for data transmission and display; peripheral and interface units for particular applications; special software to support these.

III. METHODOLOGIES

Methodologies are derived from broad areas of applications of computing which have common structures, processes, and techniques.

1. NUMERICAL MATHEMATICS: includes numerical algorithms and their theoretical and computational properties; computational error analysis (for rounding and truncation errors); automatic error estimates and convergence properties.

2. DATA PROCESSING AND FILE MANAGEMENT: includes techniques applicable to library, biomedical, and management information systems; file processing languages.

3. SYMBOL MANIPULATION: includes formula operations such as simplification and formal differentiation; symbol manipulation languages.

4. TEXT PROCESSING: includes text editing, correcting, and justification; the design of concordances; applied linguistic analysis; text processing languages.

5. COMPUTER GRAPHICS: includes digitizing and digital storage; display equipment and generation; picture compression and image enhancement; picture geometry and topology, perspective and rotation; picture analysis; graphics languages.

6. SIMULATION: includes natural and operational models; discrete simulation models; continuous change models; simulation languages.

7. INFORMATION RETRIEVAL: includes indexing and classification; statistical techniques; automatic classification; matching and search strategies; secondary outputs such as abstracts and indexes; selective dissemination systems; automatic question answering systems.

8. ARTIFICIAL INTELLIGENCE: includes heuristics; brain models; pattern recognition; theorem proving; problem solving; game playing; adaptive and cognitive systems; man-machine systems.

9. PROCESS CONTROL: includes machine tool control; experiment control; command and control systems.

10. INSTRUCTIONAL SYSTEMS: includes computer aided instruction.

SYLLABUS, INFORMATION SCIENCE IN A Ph.D. COMPUTER SCIENCE PROGRAM *

Course 1. Data Structures and Information Organization

Review of elements of set theory; Vectors and vector matching operations; Matrix operations and representation: row and column lists, row chained and column chained matrices, sparse matrices.

Tree operations and representation: right and left list matrix, chain list matrix, partitioning and transformation to optimal form.

Lattices and graphs: list matrix, level indication, connection matrix, graph matching methods.

Representation of structured operands: linear and chained representation, forward, backward, and block chaining, partitioned representation.

Storage pools: dimension and address ordered, marked pools, pushdown stores, last-in-first-out and first-in-first-out disciplines.

Search and sorting methods: sequential scanning, controlled scanning, key-address transformations, overflow procedures, chaining methods, serial sorting, internal sorting, sort evaluation.

Prerequisite: Knowledge of machine language programming and possibly a course in discrete algebra.

This course is an introduction to structured operands as well as their representation and manipulation. It describes the constructs of interest in automatic information processing systems, and introduces the principal types of required operations.

Course 2. Time-Sharing Computer Organization

Introduction to multiprogramming environment: user environment, supervisory system.

Addressing techniques: relocation, base registers, two-dimensional addressing, virtual memory, pages and segments.

File organisation: file access and protection mechanisms, page and segment management, page turning methods, search methods.

Traffic control: priority control, process switching, scheduling algorithms.

Program intercommunication: foreground and background work, storage management, storage allocation methods.

Prerequisite: Knowledge of machine language programming and standard computer organization.

This is an introduction to the multiprogramming computer environment where real-time (foreground) processing takes place simultaneously with batch processing (background) work. The course might best be scheduled following course 1.

* See ref. 36

Course 3. Language Structure and Syntactic Analysis

Syntax and semantics of arithmetic expressions: Backus Normal Form representation, translation from parenthesized to parenthesis-free notation, use of pushdown store for translation.

Precedence grammars: operator precedence, syntactic analysis of precedence grammars.

Context-free grammars: recognition methods, top-down and bottom-up algorithms, normal form for context-free grammars.

Structure of natural language: concepts and relations, triplet structure, syntax and semantics.

Context-sensitive and transformational grammars: use in analysing natural language, recognition methods, efficiency criteria.

Prerequisite: Course 1

This course describes various models of the structure of natural languages, and methods for the automatic syntactic analysis of natural languages.

Course 4. Text Analysis and Automatic Classification

Information models: entities and relations, term vectors and vector mappings, tree and graph models, matrix and lattice models, general diagram model.

Text analysis: language characteristics, word relations and relational indicators, transformation to formal entities, distance concept, text comparisons and transformations.

Thesaurus operations: semi-automatic and fully-automatic construction, thesaurus set-up operations, thesaurus look-up methods, suffix-stem operations, phrase detection, hierarchy set-up and look-up, hierarchical expansion operations.

Statistical operations: term-document mapping, property vector operations, statistical associations, term and document similarity, linear associative retrieval.

Automatic classification: eigenvalue analysis, clustering methods, classification vector, use in searching and retrieval.

Syntactic operations: automatic content analysis, phrase processing, syntactic tree matching.

Basic retrieval process: keyword matching, direct and inverted files, combined file system, vector merging and matching, vector matching of cluster vectors, iterative search methods.

Prerequisite: Course 1 and optionally course 3.

This is an introduction to automatic text analysis methods of the kind useful in automatic text processing and retrieval systems.

Course 5. Information Retrieval System Design

Information dissemination process: composition and typesetting, classification and analysis, abstracting and indexing, retrieving and evaluation.

Information centers: document depots and libraries, abstracting and indexing services, information analysis.

Input operations: input conversion and validation, encoding and editing, numeric and alphabetic codes, special-purpose codes, superimposed coding, query statement formulation.

File organization: bucket assignment, disk and tapestrip organization.

Search strategy: association coefficients, search and look-up operations, multi-level search, iterative negotiated search, adaptive retrieval strategy.

Output operations: dictionary and text display, relevance feedback, query modification.

Language design: query languages, domain and semantic properties, conversational system.

Retrieval evaluation: environment and parameters, recall and precision, determination of recall value, macro and micro evaluation, pair-wise comparisons, significance computations.

Prerequisite: Course 1 and possibly course 2; also possibly an introductory statistics course.

This covers the design of automatic retrieval systems and gives examples of the principal search and retrieval operations (exclusive of automatic text analysis).

Course 6. Automatic Text Processing Systems

Special purpose equipment: character recognition, optical film scanning, typesetting and photocomposing, storage equipment, micro-storage equipment, teletypewriters and display equipment, alphanumeric and graphical displays, communications and transmission, card and film equipment.

Auxiliary information services: text editing systems, automatic publication systems, paraphrasing systems, index and glossary production, citation indexing, selective information dissemination, concordance preparation.

Abstracting and indexing: term-oriented indexes, document oriented indexes, automatic extracting, term and sentence significance, automatic abstracting.

Data-base retrieval: organization of data base, semantic interpretation, extension of data base, automatic deduction.

On-line retrieval: conversational systems, console operations, tutorial sequences.

Applications: information networks, management information systems, interlibrary systems.

Social problems: file ownership, copyright problems, privacy protection.

Prerequisite: Course 1 and possibly course 5

This covers the design and operations of data-base retrieval systems and information services other than retrieval.

SHORT COURSE, *FUNDAMENTALS OF INFORMATION RETRIEVAL SYSTEMS*

American Management Association, Jan. 1969 *

I. UNDERSTANDING THE INFORMATION PROBLEM:
PREREQUISITE FOR INFORMATION RETRIEVAL
   A. The "Qualitative" Nature of the Problem: The
      Communication Process
   B. Various Models and Representations of the Communication
      Process
   C. The Undefinability of "Information" and Definability of
      Some of Its Properties — Implications for Retrieval Systems
   D. The Retrieval System as a Part of the Communication
      Process and as One of a Number of Answers to the
      Information Problem, Need for Integration
   E. The "Quantitative" Nature of the Problem; Literature
      Growth, Patterns and Organization — Implications for R.S.

II. INFORMATION RETRIEVAL SYSTEMS: AN ANALYTIC
VIEW
   A. The Basic Systems Concepts: Definition of a System;
      System Purpose(s); Functions as Implementation of
      Processes; Environment; Feedback; Relations Between
      Components
   B. Application to Retrieval Systems: Definition of Components
      and Subsequent Statement of Operational Alternatives;
      Construction of a Model
   C. The Minimum Purpose Components: Users and Discipline
   D. The Minimum Function Components: Acquisition; Subject
      Analysis (Indexing); File Organization; Question Analysis;
      Searching Procedures; Dissemination
   E. Function Subcomponents: The Processes Represented as an
      Interaction of System Mechanics (e.g., Rules, Policies,
      Equipment) and Human Factors (Operators)

III. USERS: THEIR PLACE AND ROLE IN RETRIEVAL
SYSTEMS
   A. The User as the Focal and Central Point of Any Retrieval
      System; Implications for Designers and Operators
   B. What Do We Know About Users: A Survey of User Studies
      with General Conclusions; Criticisms and Limitations
   C. The Preference Studies: The Rating of Types of Information
      Dissemination and Information-Carrying Media; Variables
   D. Studies of Communication Behavior. The Approach from the
      Point of View of Users
   E. Usage Studies: The Approach from the Point of View of Any
      Communication Medium
   F. Flow of Information Studies: The Approach from the
      Point of View of the Communication System(s) in a
      Given Area

IV. STUDYING THE USERS WITHIN ORGANIZATIONS —
METHODOLOGIES FOR PRACTICE
   A. Characteristics of Users Essential to a Retrieval System; The
      Influence of Well-Defined Organizational Boundaries, the
      Environmental Factors
   B. General Advantages and Limitations of Particular User Study
      Methodologies; Methodologies as Derived From Sociology,
      Psychology, Marketing Research; Rejection of "Opinion
      Polls" as Useful Studies
   C. The Survey Method: Questionnaires, Interviews;
      Construction and Examples of Questionnaires; Conduct of
      Interview, Possible Analyses and Conclusions
   D. The Observational Method: "Living" with the User;
      Specification of Users Work and Relating it to Information
      Requirements; Examples of Different Techniques Used in
      Observation; the "Diary" Method
   E. The Experimental Method: Selection of Representative
      User Sample; Provision of a Variation of Experimental
      Information Services (Not Retrieval Systems); Drawing of
      Conclusions, Indirect Studies
   F. Relating Results to the Retrieval System

V. DATA BASE OF RETRIEVAL SYSTEMS: SELECTION.
ACQUISITION AND PREPARATION FOR INPUT
PROCESSING
   A. The Variation of Data Base in Retrieval Systems: Books,
      Periodicals, Journal Articles, Monographs, Technical Reports,
      Internal Reports, Correspondence, Technical and Scientific
      Data, Other Graphic Data (Pictures, Blueprints) Secondary
      Publications (Indexes, Abstracts) Etc., Relation of Data Base
      to all Operations of Retrieval Systems

   B. The Basis for Selection: Tools, Sources and Policies;
      Decision-Making Processes Encountered in Selection,
      Quality Judgments
   C. Acquisition Procedures as Technical or Inventory Processes
      Administration Problems; Possibilities for Automation
   D. Data Preparation Techniques for Further Processing e.g.,
      Keypunching, Data Logging, Review, Editing, Correction
   E. The "Information Center Approach" to Data Inclusion;
      Highly Qualitative and Critical Evaluation Prior to Input

VI. CONTENT ANALYSIS OF DOCUMENTS:
ALTERNATIVES FOR INDEXING
   A. The Process of Indexing Represented by at Least Two
      Decision-Making Procedures: a) Analysis — Decisions on
      What to Index and b) Translation — What Particular Index
      Terms to Use
   B. The Basic Hypothesis of Coordinate Indexing, the Most
      Frequently Used Indexing Scheme in U.S.; Limitations
   C. The Variety of Indexing Languages Based on Coordinate
      Indexing; Keywords, Thesauri as Semantic and Relations
      Controls
   D. Syntactic Controls: Roles and Links
   E. Statistical Association Indexing of Full Text Natural
      Language
   F. Citation Indexing, Subject Headings, Classification
   G. Auto Indexing, Auto Machine Indexing Problems and
      Solutions

VII. HANDLING OF INPUT IN A COMPANY — CASE STUDY
A detailed presentation of operational procedures, including area
and machines, in handling of input — acquisition, controls, in-
dexing, etc. — within a company. Problems encountered and
solutions considered. Examples of work sheets, instructions and
other material.

VIII. THESAURUS: AT PRESENT THE MAJOR VOCABULARY
CONTROL TOOL; DESCRIPTION AND CONSTRUCTION
   A. Definition of a Thesaurus, The Various Functions of a
      Thesaurus in Input and Output, the Major Function,
      Specifying a Terminology of a Field
   B. Thesaurus as a Pragmatic Viewpoint Control — Equalizing
      the Scope; as a Semantic Control — Specifying the Meaning,
      as a Grammatical Form Control, as a Control of Synonyms
      and Near-Synonyms
   C. The Pragmatic Classification Features and Functions of a
      Thesaurus, the "Hidden" Classification of a Thesaurus, the
      Specification of Generic, Specific and Related Terms for a
      Thesaurus Entry
   D. Considerations and Methodologies for Construction, Broad
      Thesaun and Relation to Specific Needs, Limitations of
      Thesauri
   E. Adopting an Existing Thesaurus for Usage Within an
      Organization, e.g., How to Adopt the EJC Thesaurus
      Within an Engineering Company

IX. COMPUTER FILES FOR RETRIEVAL SYSTEMS: THEIR
ORGANIZATION AND STRUCTURE
   A. Basic Considerations for File Organization: Demands,
      Needed Capacity and Speed, Hardware Limitations,
      Software Availability, Economics, Data Structure
   B. Basic Logical Structures for Internal Manipulation of IR
      Files, Boolean Algebra and Its Limitations; Data Coding
      Schemes and Techniques
   C. Most Often Encountered File Organizations in IR Systems:
      Serial and Inverted Files; Advantages and Limitations;
      Combined Files and Other Variations, Time and Cost
   D. Highly Structured Files — the Trend Into the Future, List
      Processing; String Manipulation; Chaining; Direct and
      Indirect Addressing; Reordering of Files, Complex
      Unresolved Problems
   E. Importance of Choosing a File Structure Appropriate to the
      Bulk Storage Medium: Tape-Oriented Systems; Discs and
      Drums; Associative Memories, Real-Time Systems

X. NONCOMPUTER FILES — PHOTO AND FILM
EQUIPMENT
   A. A Survey of Non-Computer Equipment Available for File
      Storage, Integration of such Equipment with the Computer,
      Its Place in a Retrieval System

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13. ABSTRACT

The possible impossibilities -- these are the products of discovery, invention, and innovation. How do they come about? This was once a question that historians and philosophers pondered over. It is now a question of import to governors of nations, to educators, to economists, to captains of industry, and to managers of laboratories. For the possible impossibilities are at the root of technological change, and technological change is grist for the mill of economic progress. A conjecture, supported by logic and experience if not by scientific proof, is that the possession of knowledge as well as a spirit of curiosity and imaginative prowess are major attributes of those who make the impossible possible. Proposals, experiments, and programs that are under way to test this conjecture constitute the subject of this paper. Specifically, the paper considers two interdependent vehicles for producing and promoting technological change. One pertains to the realm of information handling -- systems for storing and retrieving information, and entrepreneurs for disseminating it and stimulating its scientific and economic exploitation. The other pertains to the role of education as a prime mover in creating a climate for change. In preparing individuals to become agents for change, education is not only altering its own structures, but it is also establishing new patterns of communication and new channels of information flow with other sectors of society. The process of technological change is not the exclusive province of the information and education communities. Since these groups are at the source of activities that initiate the process, however, they can be expected to contribute to large-scale effective management of technological change.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Technology transfer						
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Education						
Engineering						
Information scie..ce						
Computer science						